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The Penetration System of Orchard Spraying

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The Penetration System of Orchard Spraying

The modern farmer measures the value of his spraying by the results he secures. He sprays to protect his fruit and trees from insects and fungous diseases. A satisfactory spraying system must give this protection with the least expenditure of money and of labor.

The keynote to successful spraying is thoroughness, and thoroughness means one hundred per cent of clean fruit. Every wormy or scabby apple, every curled or scaly peach tree increases the cost of production and lessens the quantity of marketable fruit.

While most of the pests occur on the surface of foliage and bark, within easy reach of the spray, a great many are located within cracks and crevices, under bud-scales, and in the calyx cup; or are so oily that they are hard to wet. In the matter of practical control it is these protected pests which must be reached. The spray must wet through the wool of the woolly aphis, reach the aphis eggs behind the swelling buds, thoroughly coat scales and fungous spores, wet the orchard mites hiding in the innermost crevices of the bark, and place arsenic for the codling worm beneath the fleshy stamens of the apple blossom. Any spraying system that will reach these pests will easily control those on the exposed surface. Thoroughness in spraying, therefore, implies penetration.

The Penetration System of Spraying

The method which in our experience has proved to be most effective in producing these results calls for the following equipment:

1. A nozzle which will produce a coarse penetrating spray.
2. A crook.
3. A high pressure pump.
4. A "tower" for tall trees.

The Nozzle

In general, spray nozzles are of two kinds: the hollow-stream, and the solid-stream types. The former, variously known as the Vermorel, mist, cyclone, whirl, or disk nozzle, breaks up the liquid into fine particles, which leave the nozzle as a hollow cone of spray. Obviously such minute particles quickly lose their momentum, because of the resistance of the air, and thus nozzles of the mist-type have but short range. They are, therefore, not adapted to a system of spraying requiring penetration.

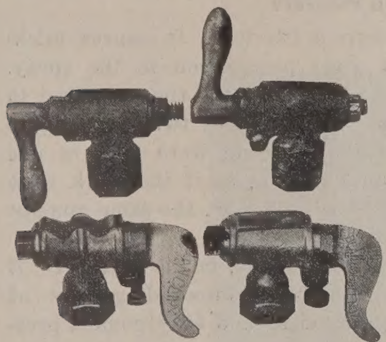
1. The Vermorel Nozzle, half size. Such nozzles have a small opening and clog easily. They produce a cloud of mist that has no penetration.

The solid-stream nozzles used for orchard spraying are commonly known as Bordeaux, clipper, or blizzard nozzles. In these a stream of liquid is forced against a deflecting lip which produces a fan-shaped coarse driving spray. Not until it reaches some distance from the nozzle does this stream break into drops and these retain their penetrative power at long range. Such nozzles are suitable for a penetration system of spraying.

The Crook

Most buds and blossoms point upwards. To spray up into the trees from the ground does not place the spray behind such buds nor into the blossoms. Effective spraying calls for a downward-directed spray. With a straight rod, this down-

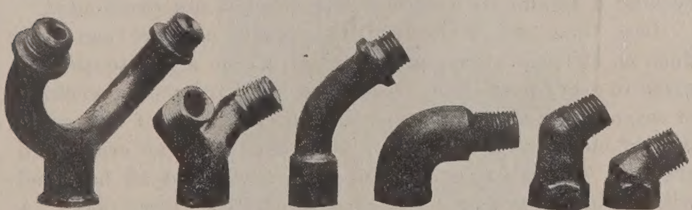
ward direction is attained only by the falling spray, and such spray has lost its penetrative power. When the nozzle is



2. Bordeaux Nozzles, half size. Such nozzles produce a fan-shaped driving spray, and are adapted to a penetration system of spraying.

joined to the rod by a crook, the spray can be thrown downward, squarely into the desired places.

Not all parts of the tree, of course, can be reached by a downward-directed spray, but the crook makes it easily possible to point in any other direction also. Any sort of spraying will reach the easy places; the crook is needed to put the spray into the difficult places.



3. Various forms of crooks. The second (a Y for power spraying) and the last (an L for the hand pump) are the best forms.

The crook, furthermore, very greatly lessens the labor of spraying by its lifting action when spraying downward. The back action of a Bordeaux nozzle, at two hundred fifty pounds pressure, amounts to nearly three pounds. Without the crook this recoil is added to the weight of the rod and the hose. With the crook the back action, operating at an angle

at the end of the extension rod, lifts the rod and relieves the operator of most of the weight.

High Pressure

The purpose of high pressure is two-fold: It assures quickness of application, and it gives penetration to the spray. Doubling the pressure practically halves the time required to spray. With a given pump, it takes about twice as long to spray at fifty pounds as if the spraying were done at one hundred pounds, or four times as long as if the work were done at two hundred pounds. In each case, the same amount of spray material is required to cover a tree.

In the Offner orchard at Walla Walla, in the year 1910, it took twenty-two minutes to apply two hundred gallons of spray to nineteen trees at two hundred and fifty pounds pressure. When the pressure was reduced to one hundred twenty-five pounds, it required forty-five minutes to apply the two hundred gallons, and again nineteen trees were covered.

High pressure means as much pressure as the pump will produce. The ideal high pressure is two hundred fifty pounds. More than this is not needed in practice, and, moreover, is sometimes harmful to the pump and hose. The pressure gauge, however, should read to three hundred pounds because it retains its accuracy longest when not overloaded.

Less than two hundred fifty pounds pressure can produce an efficient spray, provided extra time and attention be given to every part of the tree. Even the hand pump, working at seventy-five pounds, can produce perfect fruit, if the nozzle is held close enough to every twig and to every crack and crevice. The calyx-cups of an apple tree could all be filled with a pipette-syringe if enough time and care were taken. A high pressure furnishes a sweeping spray, having a range effective for many feet, and assures thoroughness of application. With a pressure of two hundred fifty pounds, branches five to ten feet from the nozzle can be effectively reached, since the spray forces its way through the foliage. If the pump does not work steadily, as would be indicated by a fluctuating pressure gauge, it is not the average pressure that determines how well the application is made, but the lowest pressure recorded.

4. The penetration system of spraying in practice. Clipper nozzle, crook, 300 pounds pressure, and the tower complete the outfit.

The Tower

When trees are over thirteen feet tall, their tops should be sprayed from an elevation and not from the ground. Usually a detachable platform or "tower" is built over the spray wagon, and is provided with a waist-high railing, or with a straddle built like a saw-horse, to enable the operator to reach out over the trees. The lower part of the tree, however, should be finished from the ground.

The Method of Application

When spraying a tree, the operator begins at the tips of the branches, stroking down the branches, first on one side, then on the other. As the spraying progresses he passes around the tree, repeating the stroking on the remaining branches. With a good equipment, on trees less than fifteen feet in diameter, such sweeping from the tips of the branches down will drive the spray through most of the tree, so that groups of branches can be sprayed at one time and no particular attention need be given to the inner portions of the tree. The stroking movements should not be too rapid or they become tiring to the operator.

When trees are so small that they can be sprayed from the ground it is advisable to complete each tree before passing on to the next. Two rows will thus be finished on one trip through the orchard, and the outfit can return between the next two rows. When the trees are larger, so that it is difficult to drag the hose around sideways, it is better to spray that half of the tree nearest the outfit, leaving the other half to be sprayed on the return trip down the next interval.

A tree properly sprayed will drink up a certain definite amount of spray. This amount is independent of the pressure used. It depends on these factors:

1. The season of the year; whether the tree is dormant or in bud, bloom or fruit.

2. The spray used; oil sprays spread further than does sulphur-lime.

3. The habit and form of the tree: the number of branches, blossoms, leaves, and fruit; whether the branches are erect or spreading.

When the buds are swelling, a much greater amount of liquid is required for effective spraying than if the application is made a month earlier. The swelling buds overlap many eggs and spores which earlier in the season were clustered about them in easy reach. The calyx-application is the most variable spraying. The open blossoms absorb an astonishing amount of liquid. For this spraying, the number of blossoms on the tree is the chief factor. It will do no harm to over-spray, but a little watchfulness will show when the clusters are properly filled and there need be little drip.

Test the thoroughness of the application by an examination of the difficult places to reach. According to the object of the spraying, search the tips of the branches, the axils of the buds, the cracks of the bark, the further side of the branches, the inner calyx-cups. If these are not thoroughly wetted, the spraying is not being effectively done, and one hundred per cent results should not be expected.

In general, at the calyx-spraying for codling moth, count on applying one gallon of spray to every two bushel-boxes of expected fruit; but this rule should not be too rigidly followed.

The following table gives some typical cases, showing the amount of spray required under certain practical field conditions at the calyx application:

Year	Location	Orchard	Variety	Age......	Gallons, per tree.....	Boxes......
1907	Walla Walla	Lennen	Ark. Black	26	20	35
1907	Wenatchee	Lanham	Ben Davis	10	7.5	14
1908	Wenatchee	Lanham	Ben Davis	11	10	19
1909	Wenatchee	Lanham	Ben Davis	12	10	15
1910	Walla Walla	Offner	Jeffries	20	20	35
1910	Garfield	Smith	Jonathan	7	3	11
1911	Chehalis	Donahoe	Baldwin	16	3.5	8

Average number of gallons of spray applied, per box of fruit produced, 1.9.

As these figures indicate, the amount of spray used at the calyx spraying is chiefly determined by the number of blossoms and bears little relation to the age or general size of the tree.

At the second spraying for codling moth, after the calyx-cups have closed, one-half the amount of liquid will suffice. Later the increased leafiness takes a larger quantity. Naturally the dormant application consumes a much smaller amount of spray, but the waste is proportionately greater, owing to the distance between the bare limbs.

The main expense involved in spraying is cost of labor. The system of spraying that empties the tank in the shortest time is the most economical in labor cost. The number of nozzles used and the size of their orifices determine the quickness of application, but since the capacity of a pump is limited to a definite number of gallons per minute, the arrangement of nozzles can not be selected at pleasure. Never use so many as to let the pressure down.

Bordeaux vs. Vermorel Nozzles

The largest size of orchard nozzle has an orifice of one-tenth of an inch in diameter. This nozzle, called the clipper, has a semi-circular deflecting lip which lessens the drip. The usual Bordeaux nozzles with straight lips have smaller openings and correspondingly smaller capacities. At two hundred fifty pounds pressure, the clipper nozzle will pass three gallons per minute.

5. The semi-circular lip of the Clipper nozzle prevents much of the drip. This is the best form of nozzle for orchard spraying. One-half natural size.

Because of friction in hose, cut-offs, etc., the amount of liquid delivered by two nozzles on a rod, or by twice the pres-

sure, is not exactly doubled. In some tests with a Magic hand pump, a Bordeaux nozzle, partly closed, delivered two and one-half gallons per minute at two hundred pounds pressure, but at one hundred pounds it required one minute and fifty seconds to furnish the same amount. Similar tests with a small-cap Vermorel showed that this nozzle had about one-third the delivery of the Bordeaux. At two hundred pounds it required three minutes and fifty seconds to run out the two and one-half gallons, and, at one hundred pounds, the time was extended to five minutes and thirty seconds.

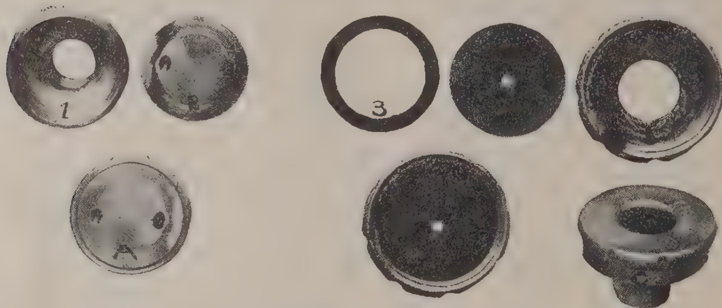
The drop in pressure at the nozzle is considerable. The larger the nozzle opening, or the more friction interposed by cut-offs of small bore, or by lengthy hose, the greater is the drop in pressure. At the Fourth National Apple Show in Spokane, in 1911, four different makes of power pumps were operated at a pump pressure of two hundred fifty pounds to test this drop. A pressure gauge was attached to the end of the rod next to the nozzle, with the following results:

		With 1 Clipper nozzle		With 2 Clipper nozzles	
Outfit	Pressure at pump	Pressure at nozzle	Gal. per Min.	Pressure at nozzle	Gal. per Min.
1	250	225	3.00	175	5.00
2	250	210	2.00	180	2.73
3	250	160	2.50	125	3.30
4	250	225	1.75	215	2.80

Mist-spray nozzles are built on the eddy-chamber principle. The liquid tangentially enters a chamber, whirls around before leaving the orifice in the center at one end, and emerges as a hollow cone of fine mist-particles. The very structure of the nozzle checks the pressure of the pump, and the resistance of the air to their misty spray destroys whatever penetrative power is left. Why should high power be demanded of the pump to be all taken out at the nozzle?

A reamed-out Vermorel, or a disk nozzle with large opening will undoubtedly deliver more liquid than one with a small opening, but still the eddy-chamber destroys the pressure and these nozzles likewise lack full penetrative power. In a com-

parative test of small and large Vermorels operated at one hundred pounds pressure, where the force of the spray was measured by a spring balance, a small opening gave a pressure, at six inches from the nozzle, equivalent to sixty-five grams. The same nozzle with a larger opening again recorded sixty-



6. Dissection of a Disk Nozzle. A slotted disk (2) inserted in the base (1) provides a whirling spray. This rotates in a chamber formed by a rubber washer (3) overlaid by the perforated steel disk (4) and held in place by the cap (5). The cap and chamber (B) screw over the entire base (A) to form the complete nozzle (C).

five grams. A Bordeaux nozzle used in the same way produced a force of one hundred seventy grams. Two feet from the nozzle the pressure from the mist-spray was too slight to be recorded, whereas the Bordeaux nozzle had spent little of its force.

7. Some forms of disk nozzles. Such nozzles should not be used for the dormant spraying nor for the calyx application, nor where penetration of the spray is demanded.

There is a fancied objection to the Bordeaux nozzle that it is wasteful of spray. This may be answered by the countercharge that the Vermorel is much more wasteful of labor, and

labor usually costs much more than spray material. But is the Bordeaux nozzle actually more wasteful of spray than is the Vermorel? The solid stream places more spray per unit of time upon the trees, but that is what the spraying material is for. The spray-tank is not intended for long-time storage of the liquid. If the operator stayed with each tree as long as if he were using the mist-spray some material certainly would be wasted, but that is neither necessary nor desirable. Aside from the disagreeableness of spraying, it is advantageous to finish quickly for more serious reasons. The spraying period is often limited to a few days to catch blossoms in receptive condition, or to reach a pest while it is most vulnerable. A short period requires more rapid application. Another fancied objection to the Bordeaux nozzle that is periodically presented to the public is that its tendency to over-spraying causes the liquid to gather in drops to run from fruit and foliage. While the skin of the apple is more or less waxy and difficult to wet it is practically impossible to give a uniform coat to every part of every fruit with the mist spray. When the near-side of an apple is properly coated the off-side is scarcely wetted; while if the spraying is continued so as to give a uniform coating of mist particles to the further side of the apples, the near side will be over-sprayed. For this reason the commercial grower should not depend on "peppering" his fruit with particles of mist, but should drive the spray with force, giving no heed to the running together of droplets. A close examination of the "peppered" fruit would disclose that it is less well sprayed than when properly drenched, for until the droplets touch there are unprotected spaces between. Moreover, the solid-stream nozzle directly places the poison where it is wanted, while the circle of mist literally "beats around the bush." It is small wonder that the commercial grower often speaks of the mist-spray as "missed-spray."

The Use of the Crook

The crook is a development from the old "under-sprayer," but its purpose is quite different, since it serves mainly as an over-sprayer. Its most convenient form is a short brass coupling at an angle of about sixty degrees. The nozzle should be

set so that its fan-spray emerges crosswise and not lengthwise of the rod. For power spraying, the Bean Spray Pump Co. has produced an efficient angle-Y, by which two nozzles can be attached to the rod at the proper angle. This coupling points the nozzles further apart than usual, so that their fan-shaped streams just overlap, and thus practically doubles the effective sweep of the spray. When two nozzles are used they should be slightly turned so that their fans extend in different planes. Then their streams do not come together along their meeting line to check the force of the spray.

8. The nozzle end of the penetration system of spraying. Note that the aluminum core of the rod is deeply set in a brass ferrule which also grips over the end of the bamboo. One-half natural size.

The Spray Pump

Back of all orchard spraying, effective or non-effective, stands the spray pump. For our purposes the many varieties of pumps may all be classed in two groups: (1) low pressure pumps, and (2) high pressure pumps.

Low Pressure Pumps

Low pressure pumps utilize various sources of power. Hand, bucket, and barrel pumps make use of the strength of a man's arm or body. Small hand and bucket pumps can hardly be considered in a discussion devoted to orchard spraying. The barrel pump is often used in young or very small orchards, but it is scarcely adapted to the penetration system. Under ordinary conditions, perhaps the best pressure which it supplies is seventy-five pounds, but its usual working pressure is much less. It takes great care and much time and labor to make a spraying one hundred per cent effective with such

low pressure. The capacity of a pump is limited. With the same power, volume and pressure must vary inversely. If the pressure is to be increased the volume must be proportionately decreased, which can be accomplished by partly closing the nozzle.

A very effective type of hand pump is the orchard pump which is mounted beside a barrel. The power is supplied by throwing a man's weight on a long vertical lever, thus making possible higher pressure and a reasonable capacity. Such pumps may be worked at from seventy-five to one hundred pounds pressure, especially if two men are put on the pump. It is more effective and economical to throw out a less amount of spray at a higher pressure, than to lower the pressure and increase the volume. Practically, this implies two men at the pump and one man at the nozzle, rather than one man to pump for two leads of hose. This pump is especially useful during the first three or four years' growth of an orchard, or for the man who has but few trees.

Gas Sprayers

The use of gas or compressed air is inconsistent with a pressure method of spraying. Power for the gas outfit is furnished by attaching a cylinder of liquified carbonic acid gas to an air-tight tank containing the spray. The pressure of the gas, regulated by a cut-off, forces the spray through an outlet at the bottom of the tank and into the hose. The gas sprayer is a simple outfit, lacking complicated parts, and appeals to the grower through the ease with which its power is obtained. However, in our experience, it is a costly machine. While at the beginning of spraying any pressure may be had, by the time the tank is nearly emptied, the pressure must be diminished or the cost for power becomes prohibitive. Growers who have attempted to maintain a reasonable pressure have emptied four or more cylinders in a day's spraying; and cylinders of gas cost five dollars each. Therefore, the last of the tank of spray is applied to the trees at a pressure often as low as twenty pounds.

Moreover, the gas dissolves in the liquid in the tank in proportion to the pressure and the temperature, and as the

9. It is more effective and economical to throw out a less amount of spray at a higher pressure than to lower the pressure and increase the volume. Practically, this implies two men at the pump and one man at the nozzle, rather than one man to pump for two leads of hose.

spray leaves the nozzle it bubbles like any carbonated water. Such bubbles meet great resistance from the air and have no penetration.

Carbonic acid gas unites chemically with certain spray materials. It destroys sulphur-lime, Bordeaux, or any spray containing lime. To use the gas sprayer with such sprays, the liquid should be used hot, or should be covered with a layer of heavy oil to prevent the gas from dissolving and ruining the spray.

Compressed air sprayers are constructed on the same principle, but power is supplied by drums of compressed air, which are filled at some central station in the orchard by a special pump operated by a gasoline engine. They may be useful in hillside orchard, because of their light weight, but are not adapted to the penetration method of spraying.

Geared Pumps

Some spray pumps are geared to the wheels of a wagon, thus deriving their operative power from the horses pulling the outfit. Usually in order to attain sufficient volume the pressure is sacrificed, but there are forms of geared machines on the market that furnish high pressure with diminished volume. In the cultivated orchard, geared machines should have the tires of their wheels fitted with shoes in order to obviate skidding when worked at full capacity. Geared pumps are not suited for large orchard use, and are not to be compared with pumps operated by gasoline power. When the trees are large, not enough liquid can be pumped into the compression tank in driving from one tree to the next to do effective work. In other words, it becomes necessary to omit some trees, and to make several trips through the orchard to complete a single spraying. In a test of one of the largest and best known of the geared orchard pumps which was conducted at Wenatchee in 1907 it was necessary to drive past nine trees in order to develop capacity and power enough to spray the tenth. To have given a spraying to this orchard, comparable at all with the applications made by the gasoline engine, would have meant ten trips past each tree. Obviously such a system is not practical for the commercial orchardist.

The Dust Sprayer

The dust sprayer is a device to distribute poison, using dust instead of water as the conveyor. A bellows blows the dust into the air, and as it settles it covers the trees. Obviously such a method is incompatible with a penetration system of application. Our experience with this form of sprayer has been unsatisfactory. For codling moth it gave about three-fourths the protection afforded by the driving liquid spray, while for apple scab it proved practically worthless. It is not suited for applying fungicides nor most insecticides, and has no place in orchard spraying.

10. A small form of dust sprayer. Our experience with the dust spray in orchard use has been far from satisfactory.

High Pressure Pumps

All the practical high pressure pumps which are in use today use some sort of a gasoline engine as the source of power. They are usually called power pumps. Various types of air- and water-cooled engines of sizes varying from one to four horse power or even more, are used.

In determining the usefulness and effectiveness of a high pressure pump there are two factors to be determined: (1) the maximum pressure which it will constantly deliver under orchard conditions, and (2) the volume of spray which it will furnish.

A high pressure pump should be able to maintain a uniform pressure of two hundred fifty pounds per square inch as measured by the gauge at the pump. This is the first and most important factor to be determined in rating a pump. No matter what are the orchard conditions, whether the soil is loose or packed; whether the orchard is hilly or level, or large or small, the constant pressure of two hundred fifty pounds should be demanded of the outfit.

The volume of spray required will vary, however, with the orchard conditions. In a large level orchard, with many bearing trees to be sprayed economically, and with a good working capital available, only outfits furnishing ten to twelve gallons of spray per minute will fill the need. In a small orchard or a young orchard where the smallness of the capital or the small amount of work prohibits the use of such an outfit, a smaller one furnishing seven or eight gallons, or three or four gallons, as the need may be, should be secured. The same standards of pressure should be maintained with all of them, but the volume may be sacrificed to cheapness.

Gasoline power orchard outfits are made in four sizes:

1. One-nozzle outfits, which furnish three gallons of spray per minute, at two hundred fifty pounds pressure, thus filling to its full capacity one clipper nozzle carried on one extension rod and with one line of hose.

2. Two-nozzle outfits, which furnish five to six gallons of spray per minute, thus supplying two clipper nozzles on one extension rod.

3. Three-nozzle outfits, which furnish seven to nine gallons of spray, filling three clipper nozzles on two rods, or as is more usually the custom, using four nozzles partially closed. This size of pump is not the most economical for it requires the same number of men and horses as the four-nozzle pump, and accomplishes but three-fourths of the work.

4. Four-nozzle outfits, which furnish ten to twelve gallons of spray per minute, thus filling four clipper nozzles on two rods. For orchard use it is not necessary to get pumps of greater capacity than this. They become too heavy to pull over cultivated ground.

The size of pump to secure is determined mainly by the time required to give the calyx application, for this spraying consumes the most liquid and has available the shortest time of the season's program. The following table may be used as a guide in deciding on the purchase of a pump.

	HAND PUMP		POWER PUMP			
	Barrel....	Orchard...	1-nozzle...	2-nozzle...	3-nozzle...	4-nozzle...
Pressure, pounds	50	100	250	250	250	250
Gal. sprayed per minute.	1	2	3	5	7	10
Tank capacity, gallons...	50	50	50	100	200	200
Minutes to empty tank..	50	25	16	20	28	20
Minutes to fill tank.....	30	30	30	30	30	30
Number tanks per day..	7½	11	13	12	10	12
Gal. per 10-hour day....	375	550	650	1,200	2,000	2,400
Number men required...	2	2	2	2	3	3
Number horses required.	1	1	1	2	2	2
Labor cost, sprayers.....	$2.00	$2.00	$2.00	$2.00	$4.00	$4.00
Labor: horse and driver.	$3.00	$3.00	$3.00	$4.50	$4.50	$4.50
Total labor cost, per day	$5.00	$5.00	$5.00	$6.50	$8.50	$8.50
Total labor cost, per 1000 gal.	$13.33	$9.10	$7.70	$5.42	$4.25	$3.54
Gal. sprayed in 6 days...	2,250	3,300	3,900	7,200	12,000	14,000
No. 5-year trees sprayed.	750	1,100	1,300	2,400	4,000	4,600
No. 8-year trees sprayed.	560	825	925	1,800	3,000	3,600
No. 10-year trees sprayed	375	550	650	1,200	2,000	2,400
No. 15-year trees sprayed	225	330	390	720	1,200	1,440

How to Select a Spray Pump

No matter what the name or style of a pump, or the manufacturer's claims for its ability, its capacity should be carefully rated and the pressure and volume at which it gives its most efficient service should be determined by actual test. It is not economy to run a pump far beyond its normal capacity, or to depend either on a small pump to do the work of a large one, or to purchase a large pump to do the work where a small one is fully capable. The large power pump is as unsuited for the

newly set orchard as the bucket pump is for bearing trees. In the study and rating of the power outfit, the following points are some that should be borne in mind. All are closely related to the performance of the pump in the orchard.

Engine—Horsepower—Air-cooled engines weigh less, but usually develop less power. Water-cooled engines are now made with a forced circulation, thereby requiring but little water for cooling. If the engine is detachable from the pump it can be available for other purposes than spraying.

Batteries—The initial cost of a magneto is scarcely warranted for the grower who has little spraying to do. Batteries usually have to be replaced annually, and those supplementing the magneto alone would suffice. A magneto with friction drive must be protected from wetting or it will slip.

Pump—Number and Size of Cylinders—A triplex pump produces a more even flow than does a single cylinder. The wider the cylinder the greater the volume of spray, but the greater power required to produce pressure. **Lining of Pump Cylinders**—Bronze resists all sprays but sulphur-lime. Especially when using sulphur-lime must the pump be washed out each night. Bronze cylinder linings of some pumps are detachable for easy renewal when worn. Enamel linings are most permanent. **Rate**—A spray pump works best at about fifty strokes to the minute. If much more than this the valves operate imperfectly. **Valves**—Detachable valve seats are desirable. Valves particularly need frequent cleaning, and should be easily reached and opened. Ball valves are best. **Plunger**—Plunger cups or packing will wear out, and should be easily replaceable. **Relief Valve**—This should be of large calibre or it will soon become corroded by the grit in the overflow. Most relief valves on the market are unsatisfactory. Under change of load, e. g. when nozzles are shut off or are turned on, the pump should maintain a steady pressure. **Hydraulic Pressure Gauge**—This should read to at least 300 pounds; if too small it soon becomes unreliable. Pumps are sometimes fitted with some sort of compensating device, which regulates the speed of the engine according to the load, so as to minimize the overflow

11. A low-pressure filling pump driven by the engine can fill the spray tank in four minutes. Without this convenient accessory much time is often wasted in filling the tank between sprayings.

through the relief valve. **Accessories**—The usual accessories include: tools (pipe-wrench, pliers, screw-driver, oil-can), full lengths of hose (fifty feet preferable to thirty-five) of spray-hose quality, with end couplings extending well into hose, set in rubber cement, and securely bound to prevent unjointing under pressure; aluminum cored extension rods with end caps and quarter-turn cut-offs; crooks, L or Y, according to number of nozzles used; clipper-pattern nozzles; extra set of engine and pump parts (springs, gaskets, valve seats, spark plug). **Repair**—Possibility of securing duplicate parts quickly in replacing any part of the machine that might break.

Filling Pump—A large capacity, low-pressure filling pump furnishes about fifty gallons per minute. With suction hose it costs about thirty-five dollars. Some outfits are equipped with a rotary filling pump of somewhat smaller capacity and weight.

Tank—The two hundred gallon size is most convenient for orchard use. It may be of wood, or of metal where Bordeaux spray is not used, and of any desired shape. It should be fitted with a drain, and with a screen-filter for the suction hose. **Agitator**—The propeller type of agitator is most efficient. Agitation of the spray liquid by the overflow through the relief valve is neither economical nor efficient.

Trucks—The wagon bed should be coupled up short, and should be so built as to permit close turning without cramping the front wheels. A steel frame gives rigidity, strength, and lightness. The wheels should be broad-tired and high. If too small they mire easily.

A SCORING CARD FOR RATING POWER SPRAYERS

The following presents an abridgement of a scoring card which may prove useful to intending purchasers of power sprayers as indicating what is studied in judging an outfit. It is given here in the form of a synopsis of the principal considerations, but without ratings. Relative weightings, being

largely a matter of personal opinion, have been omitted, since they would mean but little unless a detailed account were added of the method of making the tests. For instance, consider the first subheading under engine, pump, and outfit. The type of motor, whether stationary or marine, air or water cooled, or two or four cycle, depends largely on the intended performance of the pump, and what is desirable in one case should be rated low in another. Belt or gear driving, again, each has advantages and disadvantages. We have repeatedly snapped the crank-shaft on a certain gear-driven pump when attempting to maintain a high working pressure. On the other hand, in our experience a certain belt-driven pump has slipped, when operating at full load, so as to have proved very wasteful of energy. The best capacity for the tank depends on the field conditions under which the pump must work. The larger the tank the less time is wasted driving back and forth to refill. But a large tank means a heavy outfit, and, in a hillside orchard, or in one crossed with irrigation-ditches, or where the soil is a deep dust-mulch, weight becomes a serious disadvantage.

1. GENERAL OPERATION AND EFFICIENCY CAPACITY.

Engine—

- Type of motor.
- Operating with distillate or denatured alcohol.
- Average horse power.
- Maximum brake horse power.
- Cubic feet of piston displacement per h. p. hour.
- Revolutions per minute.
- Capacity of fuel tank.
- Cooling device:
    - Efficiency.
    - Amount of heating.
- Ignition.
- Detachability from pump for other uses.

Pump—

Belt or gear drive.
Number and style of cylinders.
Diameter of pump cylinder.
Length of stroke.
Strokes per minute.
Discharge per minute at 250 pounds pressure.
Maximum operating pressure.
Capacity of air dome.

Outfit—

Tank capacity.
Filling pump: piston or rotary.
Weight.

ECONOMY OF OPERATION.

Engine—

Time lost due to engine.
Horse power hours per gallon of gasoline used.
Gallons of gasoline per 100 gallons pumped.
Gallons of lubricating oil per 100 gallons pumped.
Per cent of fuel tank capacity used per hour for operation.

Pump, etc—

Slippage(rated capacity less actual delivery).
Uniformity of pressure.
Efficiency of pressure regulator in maintaining uniform pressure when hose is cut off or on.
Drop in pressure between pump and nozzle.
Amount of overflow from pump to tank when working at normal capacity.

Outfit—

Efficiency of agitator.
Time required for refilling tank.
Ratio of weight to capacity.

ACCESSIBILITY AND CONVENIENCE.

Accessibility of Working Parts—

Valves: Ease of replacing valve-seats.
Drains, of engine, pump, and tank.

Plunger-cups or packing.
Repacking stuffing-boxes (if any).
Screws; bolts; oil-cups; pressure-regulator.
Method of taking in slack between pump and engine.
Cleaning strainer on suction hose; cleaning tank of debris.

Adaptability to Field Conditions:

Cramping of wheels in turning.
Radius of circle required in turning.
Possibility of miring in irrigation ditches or loose soil.
Draft.

Repairs—

Possibility of securing duplicate parts.
Ease of making repairs.

2. CONSTRUCTION.

Engine—

General construction:
- Durability.
- Simplicity of design.
- Exposure of working-parts:
  - Freedom from danger of breaking cogs, cranks, etc.
  - Freedom from danger on part of operator.
- Proportions of working-parts.
- Quality of materials.
- Workmanship.

Provision for drainage.
Method of feeding gasoline.

Pump—

General construction: as above.
Valves: composition and design.
Cylinder lining.
Provision for drainage.
Provision for supplying air to air-dome.
Reliability of pressure gauge.
Type of pressure regulator.

Outfit—

Tank: wood or metal; location; design suited to agitator.

Trucks: steel or wood; rigidity; strength; weight.

Wheels: diameter; width of tires; metal or wood.

Tower:

Weight, detachability; position.

With railing or straddle.

Hose—

Quality; diameter; length; number of ply.

End couplings set in rubber and bound in place, without sharp projections to catch in operator's hands.

Extension Rods—

Length: bamboo or not; aluminum, brass or iron.

Character of end ferrules (whether they slip through the hand easily, and thoroughly grip the core).

Nozzles—

Kind: quality.

Cut-offs—

Globe or ball or quarter-turn.

Anti-leak, rapidity of action.

3. COST

Accessories supplied (e. g. filling pump and suction hose; magneto; hose; rods, nozzles; tools; crooks; tower.

Ratio of cost to capacity and efficiency.

SOME PRACTICAL HINTS ON THE ENGINE PUMP

While some fruit growers may feel that the operation of a gasoline engine demands considerable mechanical ability, it is hardly necessary to forego the advantages of modern methods for such a reason. It has justly been stated that the greatest enemy of the gasoline engine is the monkey-wrench, and, bearing this in mind, the operator should not make an inquisitive dissection of his outfit whenever anything goes wrong. Gasoline engines are now so perfected that should trouble

occur it is likely to be external to the mechanism. Failure to operate usually is due to lack of gasoline or to imperfect electrical connections. Should the engine smoke, too much gasoline is being consumed; should the explosions have a hollow, popping sound, too little gasoline is being fed. Some engines designed for stationary use fail to operate on a down-hill grade, when the gasoline supply recedes from the in-take pipe. Should the engine miss fire now and then, the batteries may be weak, or some electrical connections may be faulty. Weakened dry batteries can be revived by injecting into them a dilute solution of sal ammoniac. This can be done by opening the resin capping, and after wetting the interior contents of the battery with the sal ammoniac solution, re-seal my melting the resin with a hot iron.

Stoppage of the circulation in the jacket of a water-cooled engine quickly results in overheating. The cooler may need replenishing with water, or some obstruction, such as a leaf or apple blossom, may have lodged in the system.

If the spray-liquid leaves the nozzle mixed with air, manifested by a hissing sound, the pump may be drawing in air through a leaking suction hose, or the plungers may need repacking. This is particularly likely to happen if the intake is clogged. The strainer terminating the suction hose should always be kept free from obstruction. A leaking piston in a two-way pump prevents the attainment of high pressure. If the pressure gauge fluctuates with the pump-strokes, some valve is not working. Timing the drops in pressure will indicate which valve needs attention. A good strainer on the suction intake, presenting a large surface exposure, will prevent most valve and nozzle troubles. Sudden changes in pressure, rising and dropping with the pumping, might indicate that the air dome is filled with liquid, and in this case it is well to pump in air for a few minutes.

Some general advice that may seem too patent to need mentioning is nevertheless frequently neglected. The spraying outfit should be overhauled before it is time to begin spraying. Failure to attend to this has impressed on many a grower the

importance of this point. An outfit may have finished a spraying in splendid working condition, but after an idleness of several months refuse to operate. The engine may be at fault, but most often it is the valves that stick. Such trouble is to be expected if the pump was not well washed at the end of the last spraying, particularly if sulphur-lime was used.

Bolts should be tightened to take up shrinkage and wear. The engine and pump are under a racking strain, which readily loosens bolts, and it becomes necessary to give frequent and close attention to the proper meeting of cog-teeth of the gear.

In freezing weather the engine and the pump must be drained of water at the conclusion of each spraying, else aggravating breakage or stretching may result. A frozen and stretched valve or pump-cylinder will fail to maintain pressure. During cold weather the gasoline engine pump is particularly liable to balk. Batteries are then sluggish, lubricating oil works thickly ,and even the gasoline evaporates slowly until the engine warms up in use. Priming the cylinder, possibly using for this purpose a spring-bottom oil can containing a light grade of gasoline, or heating the engine cylinder by filling its jacket with hot water, or applying heat to the gasoline feed pipe; any of these remedies will help the engine to start quickly. Should the fault lie with the batteries, it is advisable to store them in a heated room before they are to be used.

How to Calculate the Capacity of a Pump

The square of the inside diameter of the cylinder, in inches, multiplied by 0.7854 gives the area of the piston. This multiplied by the length of stroke gives the cubic contents of the cylinder. This multiplied by the number of cylinders and by the number of strokes per minute gives the capacity of the pump in cubic inches. When this capacity is divided by 231 the result is the number of gallons the pump should furnish per minute.. The actual amount of liquid supplied may be greatly reduced by leaky valves or plungers, by excessive friction in poorly constructed parts, and by the overflow at the relief valve.

Table for Calculating Pump Capacity

Diam. of Cylinder inches	Length of Stroke, in inches 2	2¼	2½	2¾	3
1	.0068	.0077	.0085	.0094	.0102
1¼	.0106	.0120	.0133	.0147	.0160
1½	.0153	.0172	.0191	.0211	.0230
1¾	.0208	.0235	.0261	.0287	.0313
2	.0272	.0306	.0340	.0374	.0408
2¼	.0344	.0387	.0430	.0474	.0517
2½	.0425	.0478	.0531	.0585	.0638
2¾	.0514	.0579	.0643	.0708	.0772
3	.0612	.0690	.0765	.0892	.0918
3¼	.0719	.0809	.0898	.0988	.1078
3½	.0833	.0937	.1041	.1146	.1250

Multiply by the number of strokes per minute, and then by the number of cylinders to get the capacity in gallons per minute. A double-acting cylinder is equal to two cylinders. The result is the theoretical maximum capacity of the pump.

Capacity Tests of Pumps

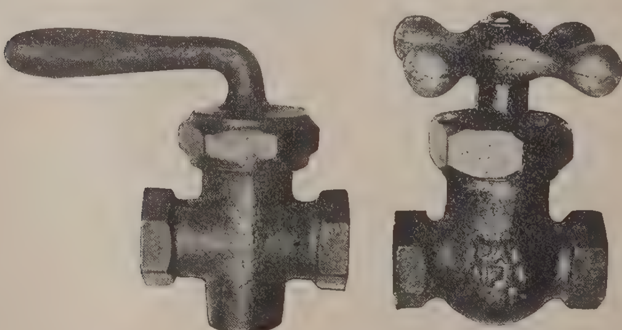
At the Fourth National Apple Show at Spokane, in November, 1911, six power pumps of different makes were tested for capacity. All were run with the same equipment of hose, rods, and nozzles. Their variation is recorded below:

	Pump No. 1			Pump No. 2	Pump No. 3				Pump No. 4				Pump No. 5				Pump No. 6	
Diam. Cylinder	2 ¾			2 ½	2 ½				2 ½				2 ½					
Length of Stroke	3			3	2 ½				2 ¾				3					
Number Cylinders	3			3	2				3				2				1 duplex	
Horse Power	3 ½			3 ½	3				3				2 ½				2 ½	
Number Nozzles	4	1	2	4 —	4	4	1	2	4	4	1	2	4—	3	1	2	3	2
Number of Rods	2	1	1	2	2	2	1	1	2	2	1	1	2	2	1	1	2	2
Number Strokes, minute	48			44	122	122			56	54			55	53			41	48
Pressure at Pump	250	250	250	250	220	250	250	250	215	250	250	250	250	175	250	250	185	200
Pressure at Nozzle		225	175				160	125			225	215			210	180		
Quarts, per minute	43	12	20	29	38	43	10	13.3	36	35	7	11.3	28	27	8	11	33	25
Theoretical Capacity, quarts	44			34	52				39	38			28	27				
Efficiency, per cent	99			86	73	83			92	92			100	100				
Tank Capacity	200			200	250				150				130				200	
Weight of Outfit	1850			1900	1400				1700				1600				1600	

The Extension Rod

The best extension rods are made of bamboo with an aluminum core. The aluminum tube is much lighter than the old-fashioned brass rods, and does not corrode. Aluminum, however, is soft and breaks easily unless the rod is well made. The weak spots are at the ends where the rod is screwed into the cut-off or crook. In the first aluminum rods the aluminum tube was threaded directly into the coupling and the bamboo was held in place by a large washer. The softness of the metal often caused the rod to break at the threads, thus necessitating delay while re-threading. The modern aluminum rod has a conical, threaded brass cap at the end with a three-inch brass tube into which the aluminum core is thrust. The cap grips the bamboo shell, holding it firmly in place, and preventing it from splitting. The new construction has eliminated entirely the main objection to the aluminum rod and makes it the most desirable type. Because of corrosion aluminum rods are not suited to sprays made with caustic soda or potash.

The lower half of the rod should be wrapped with friction tape (obtainable from any dealer in electrical or automobile supplies) so that the grasp may be firm, and the hands will not slip when the rod is wet or the pressure is on.



12. The quarter-turn cut-off and the globe valve, half size.

The rod should be provided with a good quick-action cut-off which will open or close with a single quarter turn of the

handle. The old-style globe valves formerly supplied with spray outfits were very wasteful and time-consuming. The rodman should be able to cut off the stream whenever he passes a gap in the row, goes across to the leeward of the spray during a wind, or is affected in any way by delay or accident. Because of the small relief-valves with which many pumps are equipped, the cut-off should be used as little as possible or the pressure will fluctuate. It is rarely necessary to cut off the spray when passing from one tree to the next; a rapid swing of the rod will bring the stream to the next tree without appreciable waste. The bore of the cut-off should be smooth and large so as not to obstruct the flow of the stream.

13. Section of a globe valve, half size. To shut off the stream requires several turns of the handle.

Eight feet is the best length of spray rod for trees in bearing. Longer rods become unwieldy and are hard to control. The equipment should be such that the labor and thought in lifting and moving the rod is reduced to a minimum, so that the rodman may give his undivided attention to studying his tree and doing effective, rapid, and economical spraying.

Young trees, from newly set to bearing age, do not need a long extension rod, and naturally a pump of large capacity need not be secured. The spray rod may be only a few feet long, but should be fitted with crook and Bordeaux nozzle. The nozzle may be well closed down so as to give a small stream, but the youngest tree, just as well as the oldest, requires a downward-directed, penetrating spray for best results. Even nursery stock, which is customarily dipped, can more

effectively be sprayed. The bundles of trees should be opened, and then sprayed with a driving spray directed from the tips towards the butts. This is quicker and much more effective than dipping.

14. Spray hose and connection, half size. The end should be set in rubber cement and securely bound so as not to pull out when the pressure is on. The cut in the hose shows seven-ply thickness.

The Hose

For orchard spraying the hose should be one-half inch, of the best grade, thoroughly tested, and capable of withstanding the strain at two hundred fifty pounds pressure. Each lead should be fifty feet long so as to make the rodman entirely independent of short movements of the spray wagon or the restlessness of skittish horses. He and not the horses should be the judge of when he has completed a tree. In our experience it is usually most convenient to use either one or two lines of hose, according to the nozzle capacity of the pump. More lengths of hose cause confusion, and unless the pump has excessive capacity, will increase the labor-cost per gallon of application.

* * * * * * *

Economy in spraying is measured by results as truly as by cost of application, and the system that produces highest returns is finally cheapest. Orchard enemies reproduce with remarkable rapidity. To kill **almost** all the San Jose scale, or aphis, or red spider, or canker, does not mean final protection, for by harvest time the few that escaped will have multiplied sufficiently in many cases to undo the value of the spraying. For best final results, the spraying must accomplish practical annihilation of the pests, and this can not be accomplished

by a superficial application that does not reach them in their hiding places.

That the penetration system of spraying is most successful is acknowledged by the growers of Northwestern commercial orchards, one and all. The mist-spray nozzle and pressure below one hundred pounds were formerly in vogue, and the crook was unheard of. Today these same growers have adopted the driving spray for all orchard spraying, whether for codling moth or scale, scab or aphis, in winter or summer. Their increased returns warrant the change.

Z. A. Lanham of Wenatchee, lost some four thousand boxes of apples to the codling worm in 1906, although he had given four applications of strong spray with a power pump. We sprayed his orchard as a demonstration in 1907, practically repeating his procedure, except for the substitution of clipper nozzles for his Vermorels. The total loss in this orchard in 1907 amounted to but six boxes. Like his fellow fruit-growers

15. The man in the picture holds three wormy apples, all that were found in twenty-five boxes, after the orchard was sprayed by the penetration system. This represents 99.9 per cent of fruit free from worms, or a total loss of six boxes for the orchard. The year before, when this orchard had been sprayed with Vermorel nozzles, $4000 worth of fruit had become wormy.

throughout the country, Mr. Lanham had been spraying with the Vermorel nozzle and mist-spray, and had been paying for it at the rate of about four thousand dollars a year.

In 1907 a neighboring orchard, Vermorel-sprayed, lost sixty per cent of its crop, amounting in this case to three thousand dollars. This place, the old Leonard orchard, was sprayed in 1908 with the driving spray, and the loss was reduced to one per cent.

The publicity of these demonstrations at Wenatchee resulted in such popularity of the solid stream nozzle and crook that every commercial orchardist abandoned his formerly used Vermorels, and ever since has used the driving spray for all his applications.

A canvass of the fruit growers of the Yakima Valley made in 1905 to ascertain their spraying methods showed an average of eighty-five per cent returns, with more than seven summer applications a year, and the Vermorel nozzle exclusively used. Now these growers all use the Bordeaux nozzle, give less than half the former number of applications, and their returns average over ninety-five per cent.

A series of questions regarding spraying methods submitted to the prize-winning exhibitors of the National Apple Show in 1909 and 1910 brought in over a hundred replies. These show that the Bordeaux nozzle is almost exclusively used by the Washington fruit grower. Seven of the orchardists who sprayed with Vermorels lost 12.6 per cent of their crop to the codling worm. The hundred and more who used the Bordeaux nozzle averaged a loss of 3.7 per cent. The crook was used by 91 per cent of the growers; 72 per cent of them sprayed with gasoline engine power sprayers, and 42 per cent had built "towers" over their outfits. Inasmuch as these replies represent about fifteen hundred acres, the figures give an idea of the present spraying practices in the orchards of the Northwest.

* * * * * * *

The system of spraying outlined in the preceding pages has been developed as the result of eight years study of spraying methods, during which time the authors have personally

directed the spraying of over three hundred acres of five to thirty year old trees in irrigated and non-irrigated orchards, in regions varying from ten to forty-two inches of annual rainfall, as shown in the following table. The details of these spraying experiments and a discussion of their results may be found in the bulletins and other literature listed at the end.

Year	Place	Rainfall inches	Orchard	Acres	Irrigated or not	Pest	Spray	No. Applications	% clean	Check % clean
1905	No. Yakima	9	Moxee	12	Irr.	Moth	Ars. lime	4	90	0
	No. Yakima	9	Peck	30	Irr.	Moth	Ars. lime	3	80	0
	No. Yakima	9	Wright	20	Irr.	Moth	Paris G.	5	90	44
1906	Pullman	22	W. S. C.	20	Non	Moth	Lead Ars.	4	95	50
	Wawawai	19	Downen	20	Non	Moth	Lead Ars.	4	95	42
	Spokane	19	Greenberg	17	Non	Moth	Lead Ars.	4	99	25
	Foothills	22	Williams	55	Non	Moth	Lead Ars.	4	95	15
1907	Wenatchee	8	Lanham	17	Irr.	Moth	Lead Ars.	4	100	50
	Wenatchee	8	Holcomb	10	Irr.	Moth	Lead Ars.	3	100	74
	Walla Walla	17	Lennen	2	Irr.	Moth	Lead Ars.	4	98	17
	Walla Walla	17	Offner	20	Irr.	Moth	Lead Ars.	4	96	9
	Walla Walla	17	Ross	6	Irr.	Moth	Dust	3	80	15
	Walla Walla	17	Whitney	5	Irr.	Moth	Lead Ars.	4	94	17
	Pullman	22	Aten	6	Non	Scab	Bordeaux	2	100	100
1908	Wenatchee	8	Lanham	17	Irr.	Moth	Lead Ars.	1	100	75*
	Wenatchee	8	Johnson	3	Irr.	Moth	Lead Ars.	2	97	75*
	Garfield	23	Trimble	3	Non	Scab	Sul. lime	2	92	37
1909	Kettle Falls	20	Atwood	1	Non	Scab	Sul. lime	2	100	100
	Kettle Falls	20	Webb	½	Non	Scab	Sul. lime	2	100	100
	Kettle Falls	20	Livermore	½	Non	Scab	Sul. lime	2	100	100
	Garfield	23	Trimble	3	Non	Scab	Sul. lime		100	95
						Moth	Lead Ars.	1	22	7
1910	Walla Walla	17	Offner	20	Irr.	Moth	Lead Ars.	3	94	
	Walla Walla	17	Duncan	2	Irr.	Moth	Lead Ars.	1	98	
	Garfield	23	Smith	17	Non	Scab	Sul. lime			
						Moth	Lead Ars.	1	99	65
	Garfield	23	McBroom	3	Non	Scab	Sul. lime			
						Moth	Lead Ars.	1	99	65
	Garfield	23	McCroskey	2	Non	Scab	Sul. lime			
						Moth	Lead Ars.	1	95	
1911	Chehalis	46	Donohoe	6	Non	Scab	Sul. lime	2	99	5

*Check trees imperfectly sprayed.

BIBLIOGRAPHY

The following is a list of publications of the authors of this Bulletin, dealing with various phases of the spraying problem:

1905—Melander, A. L. The Wormy Apple.
Wash, Agr. Exp. Sta. Bul 68: 1-16, 1905.

1906—Melander, A. L., and Jenne, E. L. The Codling Moth in the Yakima Valley.
Wash, Agr. Exp. Sta. Bul. 77: 1-96. 1906.

1907—Melander, A. L. Arsenate of Lead for the Codling Moth.
Report, 3rd Ann. Conv. Wash. State Hort. Assoc.: 89-98. January, 1907.

1907—Melander, A. L., and Jenne, E. L. The Codling Moth in Eastern Washington.
Wash, Agr. Exp. Sta. Bul. 81: 1-24. 1907.

1908—Melander, A. L. One Spraying for Codling Moth.
Rept. 4th Ann. Conv. Wash.. State Hort. Assoc.: 70-89. January, 1908.

1908—Melander, A. L. Only One Spraying Needed for Codling Moth.
Better Fruit, III.:11. January, 1908.

1908—Melander, A. L. Annihilating the Codling Moth.
Ent. News, XIX.: 11-13. January, 1908.

1908—Melander, A. L. Remarkable Success in Spraying the Codling Moth.
Fruit Grower, XIX.: 5-6. January, 1908.

1908—Melander, A. L. The Sulphur Lime Wash.
Wash. Agri. Exp. Sta. Pop. Bul. 2: 1-4. January, 1908.

1908—Melander, A. L. Filling the Calyx Cup.
Jour. Ec. Ent. I.: 217-220. January, 1908.

1908—Melander, A. L. Spraying for the Codling Moth.
Wash. Agr. Exp. Sta. Pop. Bull. 5: 1-7. March, 1908.

1908—Melander, A. L. Value of First Spraying for Codling Moth.
Better Fruit III.: 26-27. May, 1908.

1908—Melander, A. L. The Codling Moth in 1907.
Wash. Agr. Exp. Sta. Bull, 86: 1-19. 1908.

1908—Beattie, R. K. Apple Scab—Some Experiments with Sulphur-Lime.
Rept. 5th Ann. Conv. Wash. State Hort. Assoc.: 113-121. December, 1908.

1908—Melander, A. L. The Success of a Single Spraying for the Codling Moth.
Rept. 5th Conv. Wash. State Hort. Assoc.: 157-169. December, 1908.

1909—Beattie, R. K. Lime Sulphur Wash for Apple Scab.
The Fruitgrower, XX.: 6-7. January, 1909.

1909—Melander, A. L. The Calyx Cup Must Be Filled.
Jour. Ec. Ent. II.: 67-78. February, 1909.

1909—Melander, A. L., and Beattie, R. K. The Sulphur-Lime Wash.
Wash, Agric. Exp. Sta. Pop. Bull. 16: 1-5. March, 1909.

1909—Melander, A. L. The Single Spray for the Codling Moth.
Wash. Agr. Exp. Sta. Pop. Bull. 17: 1-4. April, 1909.

1909—Melander, A. L. Some Notions About the Spraying of Trees.
Better Fruit, IV.: 36-37. April, 1909.

1910—Melander, A. L. Combination Spray. Mixing Lead Arsenate and Sulphur-Lime Wash.
Rept. 6th Ann. Conv. Wash. State Hort. Assoc: 87-89. January, 1910.

1910—Beattie, R. K. The Work of the Washington Agricultural Experiment Station on Apple Scab.
Washington Agriculturist, III.: 17-19. February, 1910.

1910—Melander, A. L. Combination Spray. Mixing Arsenate of Lead and Sulphur-Lime Wash.
Better Fruit, V.: 47. March, 1910.

1910—Melander, A. L., and Beattie, R. K. The Sulphur-Lime Wash.
Wash. Agr. Expt. Sta. Pop. Bull. 28: 1-4. March, 1910.

1910—Melander, A. L. Spraying for the Codling Moth.
Wash. Agr. Exp. Sta. Pop. Bull. 30: 1-4. April, 1910.

1911—Melander, A. L. Some Spraying Experiences of 1910.
Rept. 7th Ann. Conv. Wash. State Hort. Assoc.: 152-158. January, 1911.

1911—Beattie, R. K. Experimental Work on Apple Scab.
Rept. 7th Ann. Conv. Wash. State Hort. Assoc.: 172-174. January, 1911.

1911—Melander, A. L. An Analysis of Western Spraying Methods.
Better Fruit, VI.: 39-41. October, 1911.

1911—Melander, A. L. The Control of the Codling Moth.
Wash. Agr. Exp. Sta. Bull. 103: 1-55. December, 1911.

1912—Beattie, R. K. Sulphur-Lime for Apple Scab; Final Report.
Report 8th Ann. Conv. Wash. State Hort. Assoc. Jan. 1912.

1912—Melander, A. L. The Control of the Codling Moth.
Wash. Agr. Exp. Sta. Pop. Bull. 45: 1-8. April, 1912.